Homework #1

1. **A solution of sodium bicarbonate is prepared by adding 45.00 g of sodium bicarbonate to a 1.00 L volumetric flask and adding distilled water until it reaches the 1.00 L mark. What is the concentration of sodium bicarbonate in units of (a) milligrams per liter, (b) molarity, (c) normality, and (d) milligrams per liter as $CaCO_3$?**

1 point

Given: 45.000 g of sodium bicarbonate in 1.00 L of water.
Solution:

a. The resulting concentration of the solution is 45 g/L. Converting this to mg/L

$$(45\ g/L)(1000\ mg/g) = 45{,}000\ mg/L = 4.5 \times 10^4\ mg/L$$

b. To find the molarity, the molecular weight of $NaHCO_3$ must be found

$$\begin{aligned} Na &= 22.99 \times 1 = 22.99 \\ H &= 1.008 \times 1 = 1.008 \\ C &= 12.01 \times 1 = 12.01 \\ 3O &= 16.00 \times 3 = 48.00 \\ \Sigma &= 84.01\ g/mol \end{aligned}$$

Then, the molarity

$$(45\ g/L)(1\ mol/84\ g) = 0.536\ M = 0.54\ M$$

c. The equivalent weight of $NaHCO_3$ is its GMW divided by the number of hydrogen ions transferred. In this case z = 1 because Na^+ is replaced by 1 H. Thus normality (N) is z*M, and in this case z = 1

$$(0.536\ M)(1\ N/M) = 0.536\ M = 0.54\ N$$

d. Change to units of mg/L as $CaCO_3$, using conversion (eq. 2-87 and lecture 4, slide 7).

$$45{,}000\ mg/L * \left(\frac{50\ mg/L\ as\ CaCO_3}{84\ mg/L\ as\ NaCO_3}\right) = 26{,}785\ mg/L = 2.7 \times 10^4\ mg/L\ as\ CaCO_3$$

2. **the following 5 chemical equations:**

1 point

Solution:

a. $CaCl_2 + Na_2CO_3 = CaCO_3 + NaCl$

Elements	Reactants	Products
Ca	1	1
Cl	2	1
Na	2	1
C	1	1
O	3	3

Note that we are short 1 Na, so multiply product NaCl by 2

Elements	Reactants	Products
Ca	1	1
Cl	2	2
Na	2	2
C	1	1
O	3	3

This yields the balanced equation:

$CaCl_2 + Na_2CO_3 = CaCO_3 + 2\ NaCl$

b. $C_6H_{12}O_6 + O_2 = CO_2 + H_2O$

Elements	Reactants	Products
C	6	1
H	12	2
O	8	3

Note that we are short 5 C, 10 H and 5 O. Multiply product CO_2 by 6 and H_2O by 6. This balances C and H on each side, and leaves a difference of 10 O. Multiply the reactant O_2 to balance equation:

$C_6H_{12}O_6 + 6\ O_2 = 6\ CO_2 + 6\ H_2O$

Elements	Reactants	Products
C	6	6
H	12	12
O	18	18

c. $NO_2 + H_2O = HNO_3 + NO$

Elements	Reactants	Products
N	1	2
H	2	1
O	3	4

Note that H is short 1, therefore multiply the product HNO_3 by 2. This causes N to be out of balance, and the reactant NO_2 should be multiplied by 3.

$3\ NO_2 + H_2O = 2\ HNO_3 + NO$

Elements	Reactants	Products
N	3	3
H	2	2
O	7	7

d. $C_4H_{10} + O_2 = CO_2 + H_2O$

Elements	Reactants	Products
C	4	1
H	10	2
O	2	3

Note that H is out of balance, but in order to keep the number of O even, we must multiply the product H_2O by 10. As a result, the reactant C_4H_{10} must be multiplied by 2.

$2\ C_4H_{10} + O_2 = CO_2 + 10\ H_2O$

Elements	Reactants	Products
C	8	1
H	20	20
O	2	12

However, the reaction is still not balanced. CO_2 must be multiplied by 8 to maintain an equal number of C. As a result, O is left unbalanced. Multiply O_2 by 13.

$2\ C_4H_{10} + 13\ O_2 = 8\ CO_2 + 10\ H_2O$

Elements	Reactants	Products
C	8	8
H	20	20
O	26	26

e. $Al(OH)_3 = Al^{3+} + OH^-$

Elements	Reactants	Products

Al	1	1
O	3	1
H	3	1

Note that Al is in balance, however we are missing two OH groups. Multiply the product OH^- by 3.

$Al(OH)_3 = Al^{3+} + 3\ OH^-$

Elements	Reactants	Products
Al	1	1
O	3	3
H	3	3

3. **You've just prepared a solution by dissolving 20 mg sodium sulfide (Na2S), and 30 mg potassium sulfate dihydrate (K2SO4•2H2O) in 1 Liter of distilled water.**

1 point

a) What is the molar concentration of sodium sulfide in this solution?
b) What is the equivalent concentration of sodium sulfide in this solution?
c) What is the molar concentration of potassium in this solution?
d) What is the concentration of total sulfur in this solution in mg/L?
e) What is the concentration of reduced sulfur (i.e., S(-II)) in this solution in mg/L?
f) What is the theoretical TDS of this solution in mg/L?

Answers:

Assemble essential data:

	Atomic Wt
Na	22.99
S	32.06
K	39.1
O	16
H	1.01

Calculate molar quantities and percentages

GFW		Amount Added mg	mMoles	%water	%Sulfur	%S(-II)
78.04	Na_2S	20	0.256279	0.00%	41.08%	41.08%
210.3	$K_2SO_4\ 2H_2O$	30	0.142653	17.14%	15.24%	0.00%

a. Molar Concentration

GFW = 2* 22.99 + 32.06 = 78.04

$$Molarity = \frac{mass/L}{GFW} = \frac{0.020g/L}{78.04g/mole} = 0.000256moles/L$$

or

0.26mM

b. Equivalent Concentration

Since z=2 for the compound (i.e., there are 2 positive charges Na^+ and Na^+, and 2 negative charges S^{-2}), then GEW = GFW/2 = 39.02, This also makes the equivalent concentration twice the molar concentration, so:

$$Normality = \frac{mass/L}{GEW} = \frac{0.020g/L}{39.02g/mole} = 0.000513N$$

or

0.51 meq/L

c. Molar Concentration of K

first determine the molar concentration of the potassium sulfate

GFW = 2* 39.1 + 32.06 + 4*16 + 2*(16+2*1.10) = 210.3

$$Molarity = \frac{mass/L}{GFW} = \frac{0.030g/L}{210.3g/mole} = 0.000143moles/L$$

or

0.143mM

Then translate this to a concentration of potassium alone

$$Molarity = \frac{0.000143moles - K_2SO_4 \bullet 2H_2O}{L}\left(\frac{2moles - K}{1mole - K_2SO_4 \bullet 2H_2O}\right) = 0.000285moles - K/L$$

or

0.29mM

d. Concentration of Total Sulfur

One approach is to determine total molar sulfur concentration and then convert to mg/L units.

$$Molarity = \frac{0.000256 moles - Na_2S}{L}\left(\frac{1 mole - S}{1 mole - Na_2S}\right) + \frac{0.000143 moles - K_2SO_4 \bullet 2H_2O}{L}\left(\frac{1 mole - S}{1 mole - K_2SO_4 \bullet 2H_2O}\right)$$

$$= 0.000399 moles - S / L$$

$$Concentration = \frac{0.000399 mole - S}{L}\left(\frac{32.06 g - S}{mole - S}\right) = 0.0128 g / L$$

= 12.8 mg/L

e. Concentration of Reduced Sulfur

The reduced sulfur is only the S in Na_2S. This is sulfur in its (-II) oxidation state.

$$Molarity = \frac{0.000256 moles - Na_2S}{L}\left(\frac{1 mole - S}{1 mole - Na_2S}\right)$$

$$= 0.000256 moles - S / L$$

$$Concentration = \frac{0.000256 mole - S}{L}\left(\frac{32.06 g - S}{mole - S}\right) = 0.0082 g / L$$

= 8.2 mg/L

f. What is the TDS

Determine the total mass of salts added, minus any water (i.e., water of crystallization).

$$TDS = (20 mg - Na_2S)\left(1 - \frac{0 g - H_2O}{78.04 g - Na_2S}\right) + (30 mg - K_2SO_4 \bullet 2H_2O)\left(1 - \frac{36.04 g - H_2O}{210.3 g - K_2SO_4 \bullet 2H_2O}\right)$$

TDS = 44.9 mg/L

4. **If 200 mg of HCl is added to water to achieve a final volume of 1.00 L, what is the final pH?**

0.5 points

pH of HCl solution

Given: 200 mg of HCl in 1.00 L
Solution:

a. Calculate molarity

GMW of HCl = 36.45

$$\left(\frac{200\text{ mg}}{\text{L}}\right)\left(10^{-3}\frac{\text{g}}{\text{mg}}\right)\left(\frac{1}{36.45\text{ g/mol}}\right) = 5.487 \times 10^{-3}\text{ M of HCl}$$

b. Moles of H^+ on ionization

$HCl \leftrightarrow H^+ + Cl^-$

so 1 mole HCl = 1 mole H^+

$[H^+] = 5.476 \times 10^{-3}$ M

c. Using Eqn 2-38

pH = $-\log(5.487 \times 10^{-3})$ = 2.26

5. **What amount (mass, in mg) of NaOH (a strong base), would be required to neutralize the acid in previous problem?**

0.5 points

From the problem above, we now know that 200 mg/L of HCl is 5.476×10^{-3} M

Since HCl has a single hydrogen ion it donates to water, and NaOH has a single hydroxide that can neutralize a single hydrogen ion, the stoichiometry of neutralization is 1:1

$$HCl + NaOH \rightarrow NaCl + H_2O$$

Therefore we need 5.476×10^{-3} M of NaOH

The GMW of NaOH is 22.99 + 16 + 1.008 = 40 g/M

So the amount of NaOH is 40x 5.476 x 10^{-3} M = 0.219 g

6. **The concentration of a chemical degrades in water according to first-order kinetics. The degradation constant is 0.2 day^{-1}. If the initial concentration is 100.0 mg/L, how many days are required for the concentration to reach 0.14 mg/L? Also calculate the half-life ($t_{1/2}$) for this decay reaction.**

1 point

Given: 1st order kinetics, rate of 0.2 d^{-1}, initial concentration = 100 mg/L.
Solution:

a. Time to read 0.14 mg/L by 1st order kinetics

$$\ln \frac{C}{C_o} = -kt$$

$$\ln \frac{0.14}{100} = -(0.2)t$$

$$-6.57 = -0.2t$$

t = 32.85 or 32.9 d

b. Half Life

$$t_{1/2} = \frac{\ln 2}{K} = \frac{0.693}{0.2d^{-1}}$$
$$= 3.5 \text{ d}$$

7. **Each mole of CaF_2(s) dissolved yields 1 mole of Ca^{2+} and 2 moles of F^- (fluoride). The solubility product of calcium fluoride (CaF_2) is 3×10^{-11} at 25C. Could a fluoride concentration of 1.0 mg/L be obtained in water that contains 200 mg/L of calcium? Show your work.**

not graded

Given: Solubility product of CaF_2 = 3 x 10^{-11} , F = 1.0 mg/L and Ca = 200 mg/L
Solution:

a. Convert Ca and F to moles/L

$$Ca = \frac{200 \text{ mg/L}}{(40.08 \text{ g/mole})(1000 \text{ mg/g})} = 4.99 \times 10^{-3} \text{ moles/L}$$

$$F = \frac{1.0 \text{ mg/L}}{(18.998 \text{ g/mole})(1000 \text{ mg/g})} = 5.26 \times 10^{-5} \text{ moles/L}$$

b. Calculate solubility of F with 200 mg/L of Ca in solution.

$$K_s = [Ca][F]^2$$

$$K_s = [4.99 \times 10^{-3}][F]^2 = 3.00 \times 10^{-11}$$

$$[F] = \left(\frac{3.00 \times 10^{-11}}{4.99 \times 10^{-3}}\right)^{1/2} = 7.75 \times 10^{-5} \text{ moles/L}$$

c. Since 7.75×10^{-5} is greater than 5.26×10^{-5}, the 1.0 mg/L of F will be soluble.